Sanguinicola from the Sudan.

By

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With Plate 18.

In 1908 [1] the description by Dr. Marianne Plehn of Sanguinicola as the only known example of a Cestode (Cestodarian) infesting the blood aroused considerable interest, and though the subsequent conclusion by Odhner in 1911 [2] that Sanguinicola was rather to be regarded as an extreme form of suckerless haematobic Trematode somewhat detracted from the significance of the discovery, yet on account of its plesio-Turbellarian structure and possible Turbellarian affinities, Sanguinicola still remains a zoological type of importance.

So far as I am aware, Sanguinicola has, up to the present, solely been found in Germany in the blood of Cyprinidae,[3] and it was therefore a source of gratification to me to discover in the large collection of slides of Helminth material made by the late Dr. A. J. Chalmers when Director of the Wellcome Tropical Research Laboratories at Khartum and kindly presented to the Wellcome Bureau by his successor, Major R. G. Archibald, some thirty specimens of Sanguinicola obtained from the blood in the heart of the Nile Siluroids,

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[1] " Ein monozoischer Cestode als Blutparasit (Sanguinicola armata u. inermis, Plehn) ", ' Zoologischer Anzeiger ', Bd. xxxiii, p. 427, 1908–9.

[2] T. Odhner, " Sanguinicola M. Plehn—ein digenetischer Trematode ! " ibid., Bd. xxxviii, p. 33, 1911.

[3] Max Lühe, " Parasitische Plattwürmer II : Cestodes " in Brauer's ' Die Süsswasserfauna Deutschlands ', Heft 18, 1910.

Synodontis schall, Bloch-Schneider 1801, and Auchenoglanis occidentalis, Cuv. and Val. 1840. Since I have not examined personally the Sanguinicola armata and S. inermis of Plehn, I am unable to say, especially in view of the somewhat diagrammatic figures and, in the case of certain organs, discordant accounts of the anatomy of these two species, whether the Sanguinicola from the Sudan is a distinct third species or not, but its structure is evidently sufficiently similar to enable me to venture to correct and amplify in some respects the descriptions supplied by Plehn and to furnish some additional evidence in connexion with the possible affinities of this organism.

My material consisted in all cases of specimens already stained and mounted in balsam. Twenty were from Auchenoglanis occidentalis and fourteen (including one very young form, three cut into horizontal and transverse sections, and four which I lost during restaining but which I had previously examined) from Synodontis schall. In length the adult or nearly adult specimens varied between 647·4 and 1,228·4 microns in length, and all were of the 'armed' (i. e. bearing spinelets on the edge of the body) type.

One external feature which Dr. Plehn has not described for S. armata and S. inermis is the presence on the surface of the body which does not carry the genital openings of a furrow or groove, shallow over the greater length of the body but deep posteriorly and terminating just anteriorly to the hind end of the animal in a distinct pocket (Pl. 18, figs. 3, 7, Z, Y, X, W, V). This furrow or groove is formed by the inturning and posterior fusion of the edges of the body, is apparently a permanent formation judging by the posterior pocket, and is similar in form to the similar body grooves to be found in such Trematodes as Hemistomum clathratum and the male Schistosoma, but differs in that it does not contain the sexual apertures and therefore cannot be of use in copulation. The edges of the body which border this furrow contain the spinelets [1] or ‘ Häkchen ’ described by Plehn, except posteriorly where the edges turn mediad in order to unite (Pl. 18, fig. 1, SP). The spinelets are distinct rods of the form shown in fig. 9, and are almost entirely embedded in the subcuticula and parenchyma save for their outer extremities, which project slightly. These spinelets attain a maximum length of about 27 microns, and they are apparently identical in nature with the chitinous spines found in the skin of many Malacocotylea.

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[1] If mounted specimens of Sanguinicola be not well flattened out, spinelets will appear to be absent on the 'edges' of the body and can only

For the reason to be supplied later when describing the genital apparatus, I shall consider the side of the body bearing the furrow as the dorsal surface, from which it follows that the genital openings are situated, as in most Turbellaria and Trematoda, on the ventral surface.

In general shape (Pl. 18, fig. 1) the Sudan Sanguinicola resembles the Sanguinicola described by Plehn. As Plehn describes, and as is evident even in preserved material, the body is highly contractile and in much contracted specimens may be a broad oval in outline.

As regards the internal organization, the two chief systems of organs to be described are the gut and the genital apparatus ; I have nothing to add to Plehn's description of the nervous and excretory systems and the general histology.

The gut, as shown in figs. 1, 4, 5, 6, is in a much reduced condition as compared with the gut in most Turbellaria and Trematoda ; but that it is a gut and not a ‘ frontal gland ’ is shown not only by the presence of a well-marked muscular sucking pharynx (PH) and by the non-glandular character of the wall of the gut sac (GS), but also by the occasional presence of distinct blood-corpuscles in its lumen (seen in two of my specimens). The anterior mouth-opening (M) is, as in all

be detected by careful focusing ; also in young specimens the spinelets are smaller than in full-grown forms and in very young forms are absent. I hardly like to suggest that a conjunction of these two conditions is responsible for the description of the S. inermis of Dr. Plehn, but it appears to me that the suggestion might be applicable. The difference of size between the two species S. armata and S. inermis quoted by Lühe is of no specific value.

blood-sucking animals, extremely minute, and this leads into a short, very narrow, though distensible channel opening into the thick-walled (when empty) elongated pharynx (PH) which extends posteriorly as far as the transverse nerve-commissure (NC). This pharynx is capable of great distension (Pl. 18, figs. 4, *c*, *d*). Its wall, when not distended, is of considerable breadth and is transversely striated, and I believe is covered externally by a layer of cytoplasm containing relatively few nuclei (judging from the appearance seen in one of my specimens, on which fig. 5 is based); but of this I am not quite certain, and Dr. Plehn may be correct in stating that nuclei are absent in this region of the gut. In most preparations it is difficult to distinguish such nuclei from the nuclei of the layer of muscle-cells (Pl. 18, fig. 1, PMUS) which is connected with the outer wall of the pharynx. From the posterior end of the pharynx to the gut sac is a narrow oesophagus (OE), with a wall much thinner than that of the pharynx and covered externally with a layer of nucleated cytoplasm. The oesphagus apparently lies ventral to the nerve commissure. The gut sac (GS), situated at the hind end of the anterior third of the body, is somewhat irregular in shape, but is more or less compact and possesses none of the distinct four or five lobes figured by Plehn. Its wall consists of a thin, occasionally nucleated, layer of granular cytoplasm. Dr. Plehn, in her first description[1] of Sanguinicola as a Turbellarian, naturally regarded the anterior canal and sac as a gut; but she states that it only contains a ‘feinen Brei’ and that blood-corpuscles are never found in the lumen, because the mouth and anterior canal are too narrow to admit of their entrance. But the mouth and all parts of the canal are capable of considerable distension, as is shown in my specimens, and in two cases I have found distinct rows and small masses of evident fish blood-corpuscles in the anterior end and hind part of the pharynx and in the sac. There is thus no question concerning the gut-nature of the anterior canal and sac, and this fact definitely settles the non-Cestode nature of Sanguinicola.

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[1] “Sanguinicola armata und inermis (n. gen. n. sp.), n. fam. Rhynchostomida. Ein ento-parasitischer Turbellar im Blute von Cypriniden”. ‘Zoologischer Anzeiger’, Bd. xxix, p. 244, 1905–6.

Sanguinicola is hermaphrodite and its reproductive organs have been well described by Dr. Plehn in her first paper,[1] but, judging by my specimens of the Sudan Sanguinicola, she has erred in several respects in her second revised description of Sanguinicola as a monozoan Cestode, as I shall indicate later.

The ovary (OV) in the Sudan Sanguinicola is bipartite in form and is extensive, occupying the margins of nearly the whole of the anterior two-thirds of the body, external to the testes, gut sac, and pharynx (Pl. 18, fig. 1). The oviduct (OVD) is median and, according to the convention I have already adopted, dorsal in position, i. e. on the side of the body bearing the longitudinal furrow (Pl. 18, fig. 2). Ovarian follicles are to be found anteriorly at the sides of the pharynx (interspersed with the muscle-cells surrounding this organ), and they extend posteriorly, on each side, opening into the median oviduct by some eight or more transverse ducts (hidden under the testes in fig. 1). Posteriorly to the last pair of transverse ducts, the oviduct, in a dorsal view (Pl. 18, fig. 1, shows the ventral aspect), turns to the right above the median vas deferens; then, becoming much dilated, bends again to the left and somewhat posteriorly, passing ventral to the vas deferens, and finally, becoming narrow, runs posteriorly on the left-hand side, to open by a narrow aperture into the distinct spherical fertilization chamber (OTP) on its posterior aspect. From the anterior side of the fertilization chamber and by a similar small opening, arises the vagina (VAGN), which is short, narrow at first, and wider after (VAGB), and opens on the ventral surface by a circular vaginal pore (VAGP), which lies at the end and at the bottom of an elongated ridged muscular oval groove (VAGR), directed to the left and posteriorly, the vaginal groove (Pl. 18, figs. 1, 7, 7Y, 7X, 8). The course of the oviduct I have above described is constant in all my specimens. I may also mention that the oviduct, fertilization chamber, and vagina are all distensible structures, but that I have never observed the openings into and from the fertilization chamber to be otherwise than narrow.

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[1] Ibid.

The fertilization chamber is a quite distinct permanent spherical dilatation, sharply demarcated from both the oviduct and the vagina by the narrow openings just referred to, and with distinctive thick walls. It usually contains a large cluster of eggs, and eggs of course are usually to be seen in the oviduct, both anteriorly and posteriorly, but I have not been able to detect either eggs or spermatozoa in the vagina, though the eggs must make their exit by this duct and spermatozoa must enter. The eggs (Pl. 18, fig. 10) in the fertilization chamber (which measure in diameter from 5·2 to 5·6 microns) and oviduct appear to be fully mature, and are certainly not the mere accidentally injected yolk-cells postulated by Dr. Plehn. One trifling and yet in a way important point to mention is that the muscular walls of the dilated portions of the oviduct, situated just below the ovaries, as well as the walls of the vas deferens, show a marked longitudinal striation, and this striation, seen in optical or actual section in slides stained with haematoxylin, bears a superficial resemblance to a mass of spermatozoa, and it was this appearance I imagine which led Dr. Plehn to assume that the portion of the oviduct behind the ovaries represented a vagina. Starting from this assumption, Dr. Plehn was logically led into the further assumptions: (1) that a second female duct was present—the duct she labelled 'Uterus' and supposed by her to be continuous in the young animal with the duct she labelled 'Dottergang' (Pl. 18, fig. 11);[1] (2) that an ootype must be situated between the bases of the two ovaries, but, it not being visible, it was necessary to assume (3) that the animal was not mature, and in view of this immaturity, (4) that the eggs plainly to be seen in the oviduct and in my fertilization chamber were only yolk-cells which had become prematurely or accidentally shed into the ' uterus '.

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[1] Dr. Plehn says in her second paper that she had previously failed to observe the 'ganz typische Cestodenvagina' full of spermatozoa, but a comparison of the figures in her first and second papers proves that the 'Dottergang-uterus' is the new second female duct figured and not the 'vagina'. In her first paper the 'vagina' (i. e. the oviduct) is shown clearly (and correctly) in all its winding course and full of eggs, not spermatozoa; whereas, in her second paper, it is represented as of the same form but devoid of eggs.

Concerning the existence of vitellaria as distinct from ovarian follicles, I am unable to speak with certainty from actual observation, since, as Dr. Plehn admits, they are not in any way distinguishable, and I am willing to allow that, if vitellaria exist, the upper part of the oviduct may function as a vitelline duct, but as regards the existence of a separate female duct, i.e. combined 'Dottergang' and 'Uterus' (Pl. 18, fig. 11) in addition to the oviduct figured by Dr. Plehn in her original communication (and by me in fig. 1) and relabelled ' vagina ' in her second paper, I am absolutely certain that, in the Sudan Sanguinicola, such a second female duct does not exist (as I can demonstrate in both whole-mounted specimens and in horizontal and transverse sections) and, since there is no shell-gland and Dr. Plehn did not observe this second female duct when first describing the genitalia, I feel tolerably certain also that it does not exist in the German Sanguinicola.[1] Further, the non-existence of a separate vitelline duct almost implies the non-existence of vitellaria, as also does the presence of globules of presumably some sort of food material in the periplasm of the eggs (Pl. 18, fig. 10). As regards the existence of an ootype, a true ootype, i.e. a chamber into which the ducts of the vitellaria and shell-gland open, obviously cannot exist, since both vitellaria and a shell-gland are absent ; but if it did, it would presumably be found next to the fertilization chamber which I have described and not between the ovaries. Finally, I can see no reason to suppose that the eggs found inside the fertilization chamber are not mature : their position alone certifies their maturity.

In short, the female reproductive system of Sanguinicola is in essentials constructed upon the plan found in many Rhabdocoelida and Polycladida, in which vitellaria are also absent and in which the oviduct is also long and opens directly to the exterior, its end part being differentiated into a fertilization chamber or passage and ootype when present and the ‘antrum femininum’ serving as vagina, and Dr. Plehn's first idea of regarding Sanguinicola as an aberrant and much modified Turbellarian has still much to be said in its favour, both from the points of view of the genitalia and the gut. Odhner's comparison of Sanguinicola with certain Malacocotylea was of course based on Dr. Plehn's second but, as I believe, erroneous description of the genitalia of Sanguinicola.

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[1] If this second female duct does exist in the German Sanguinicola, then this is radically different from the Sudan form, but this I am unable to credit without further evidence.

The testes (TES) are bounded anteriorly by the gut sac, and laterally and posteriorly by the ovaries (Pl. 18, figs. 1, 2). They consist of large ovoid or spherical capsules connected with the main vas deferens in the median line by transverse ducts. The main vas deferens (VD) is conspicuous in stained preparations by reason of its longitudinally striated muscular walls, and anteriorly it lies ventral to the oviduct. In occasional specimens there appear to be two or three main longitudinal trunks of the vas deferens anteriorly instead of one. Immediately posterior to the ovaries the vas deferens lies below the oviduct, but turning to the right (viewed dorsally) it passes above the dilated oviduct, then, becoming considerably dilated, bends sharply to the left (lying parallel with and close behind the dilated limb of the oviduct), and then, as sharply bends again to the right, where it enters the penis which lies posteriad and to the left, and opens to the right of and slightly behind the opening of the vagina. The directions in which the penis and the vagina lie are approximately at right angles to each other, and if we imagine two Sanguinicola to apply their ventral surfaces together, then the direction of the penis of one Sanguinicola will coincide more or less with the direction of the vagina of the other, one (or both) of these Sanguinicola perhaps holding on to the wall of the blood-vessel by the spiny-edged furrow of the opposite surface.

During copulation—a process which I assume to result in a mutual exchange of spermatozoa between two Sanguinicola—the spermatozoa must, in each animal, traverse the vagina and reach the fertilization chamber, where fertilization occurs. After fertilization I assume that the eggs are extruded through the vaginal pore into the blood. Since these eggs are devoid of shells, it seems to be evident that the eggs must be removed from the blood by the agency of some such external blood-sucking parasite as (in the case of the German Sanguinicola of the carp) the carp-louse, Argulus foliaceus, or (in the case of the Sudan Sanguinicola) other species of Argulidae, or perhaps a leech. In Odhner's sketch of the possible life-history of the German Sanguinicola he omitted to offer any suggestion as to how the fertilized eggs reached the Molluscan intermediate host postulated by him from the fish, other than stating that he found a ' mature ' egg, containing a miracidium, in the kidney of a carp, but to me it is difficult to believe, without further evidence, that a miracidium can develop from a shell-less egg in blood and thence take to water. All animals (except perhaps sponges and other very low forms of aquatic life) which extrude eggs into water, even when the animals themselves are living in water, and even when the eggs are not fertilized until after contact with the water, protect the eggs with shells or envelopes of one kind or another, and much more should this be the case in parasitic forms (like Schistosoma) which have to extrude the eggs first into vertebrate blood and then into open water.

As regards the external vaginal groove, this is possibly connected with the insertion of the penis, though it is difficult to understand on that hypothesis why its direction should be at right angles to that of the vagina and not in line with it.

Finally, I must state that I have adopted the convention of regarding the surface of the body bearing the longitudinal furrow as the dorsal side, because it is usual in both Turbellaria and Trematoda for the sexual openings to be situated ventrally. The fact that in certain Trematodes a similar furrow is situated on the ventral side is but of little importance in this connexion because it is probable that the furrow in Sanguinicola is a special structure adapted to life in blood-vessels, and I am by no means convinced, in view of the Turbellarian conformation of the genitalia in Sanguinicola, that Odhner is right in regarding Sanguinicola as a Malacocotylean, despite the analogies (of the gut and habitat) with Aporocotyle and Deontacylix, though it is true that the genitalia of Sanguinicola may have become secondarily simplified. The evidence of Looss[1] to the effect that a cercaria stage occurs in the life-history of Sanguinicola requires confirmation before a decision can be arrived at, and if it be confirmed, it will be of interest to know how the naked eggs liberated into the blood of the fish are transported to the intermediate Molluscan host.

DESCRIPTION OF PLATE 18.

♂, male aperture. ♀, female aperture (vaginal pore). 'DG', 'dottergang'. EE, narrow opening from fertilization chamber into vagina. EGG, ripe eggs. GS, gut sac. M, mouth. NC, nerve commissure. OE, oesophagus. OOO, narrow opening of oviduct into fertilization chamber. OTP, fertilization chamber. 'OTP', hypothetical ootype. OV, ovary. OVD, oviduct. OVDB, dilated oviduct. OVDN, narrow portion of oviduct. PEN, penis. PH, pharynx. PMUS, muscle-cells surrounding pharynx. SOL, solid posterior extremity of body behind dorsal furrow. SP, spinelets. TEP, terminal excretory pore. TES, testes. 'UT', 'uterus'. VAG, vagina. 'VAG', 'vagina'. VAGB, dilated part of vagina. VAGN, narrow part of vagina. VAGP, vaginal pore (♀). VAGR, vaginal groove on surface. VD, vas deferens. VF, dorsal body furrow. V–V, W–W, X–X, Y–Y, Z–Z, planes of sections across fig. 7 corresponding approximately to the figures of actual sections in figs. 7, V, W, X, Y, Z.

Fig. 1 (× cir. 87).—Sanguinicola viewed from the ventral aspect.

Fig. 2 (× 180).—Transverse section across Sanguinicola behind the gut sac (the convex surface is ventral).

Fig. 3 (× 39).—Sanguinicola in dorsal surface view.

Fig. 4 A (× cir. 120).—Unusually small contracted pharynx.

Fig. 4, *b*, *c*, *d* (× cir. 120).—The undistended (*b*) and distended (*c*, *d*) pharynx in three Sanguinicola.

Fig. 5 (× 530).—The undistended pharynx.

Fig. 6 (× 530).—The gut sac and opening of oesophagus.

Fig. 7 (× 260).—The posterior genital ducts and openings from the ventral aspect. V–V, W–W, X–X, Y–Y, Z–Z represent approximately the planes of the sections shown in fig. 7, V–Z (× 180).

Fig. 8 (× 530).—The posterior genital ducts and apertures magnified to show the character of the walls of the former.

Fig. 9 (× 840).—The spinelets embedded in the edge of the dorsal body furrow.

Fig. 10 (× 840).—Eggs contained in the fertilization chamber.

Fig. 11.—Diagram to show the genital ducts as figured and described by Dr. Plehn in her second paper (1908), for comparison with fig. 1.

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[1] Quoted by Odhner.